Feeding, Growth Rate and Survival of the 1984 Year-Class of Kemp's Ridley Sea Turtles (*Lepidochelys kempi*) Reared in Captivity

Charles W. Caillouet, Jr., Sharon A. Manzella, Clark T. Fontaine, Theodore D. Williams, Marty G. Tyree and Dennis B. Koi*

A feeding experiment was conducted between August 22, 1984 and February 28, 1985 on the 1984 year-class of Kemp's ridley sea turtles (Lepidochelys kempi). *Hatchlings were assigned to three treatments in a randomized block design. The treatments included two levels of feeding, high and low, represented by feeding rate (percentage of body weight per turtle per day) and food ration (weight of food per turtle per day). The high level began at 1.3 times the low level in terms of weight of food per turtle per day, and reached 2.5 times the low level by the end of the experiment. At the high level, two feeding frequencies were tested, once-daily in the morning versus twice-daily in morning and afternoon. For twice-daily feeding, the daily ration was divided into two equal portions. At the low level, only once-daily feeding was tested. Response variables included feeding rate, food ration, survival, gross food conversion efficiency, weight gain and a growth rate index. Temperature, salinity and pH were monitored during the experiment.*

Turtles that received the most food had the highest weight gains and growth rate indices. However, for the high level of feeding, turtles receiving the entire daily ration in one feeding per day had a smaller daily weight gain than those in which the daily ration was divided into two separate feedings. There was no apparent difference in the response to once-daily vs. twice-daily feeding (at the high level) as measured by the growth rate index.

Gross food conversion efficiency was either better (lower amount of food fed per unit increase in weight of turtle) at the low level of feeding or did not differ from that at the high level of feeding.

The experimental feeding levels and frequencies had no apparent effect on survival, and overall survival during the experiment was very high (95.8 percent).

Approaches used in the Kemp's ridley sea turtle (*Lepidochelys kempi*) recovery program include experimental head starting to establish a new nesting colony of Kemp's ridleys at the Padre Island National Seashore bordering the Gulf of Mexico near Corpus Christi, Tex. (Klima and McVey, 1982). Head starting involves collecting, incubating and hatching the eggs, imprinting the hatchlings and rearing the turtles from hatchlings to yearlings (9 to 11 months of age) in captivity (Mrosovsky, 1983; Caillouet, 1984; Fontaine *et al.*, 1985). Survivors in good condition and health are tagged and released into the Gulf at a size that, according to the current working hypothesis, improves their chances of survival as compared to that of wild hatchlings.

Among the objectives of experimental head starting has been the improvement of captive rearing methods. This paper describes a feeding experiment conducted on Kemp's ridleys of the 1984 year-class to determine the effects of feeding level and frequency on their growth rate, gross food conversion efficiency and survival in captivity.

Hatchlings

Padre Island-imprinted Kemp's ridley hatchlings from 19 clutches of the 1984 year-class (see Caillouet *et al.*, 1986a, Tables 3-13 and 15) were transferred from the Padre Island National Seashore to the head start facilities at the Galveston Laboratory from July 24-27, 1984. The eggs from which these hatchlings were obtained had been collected in the usual way from the beach at Rancho Nuevo. The eggs were packed in polystyrene foam boxes containing sand from the Padre Island National Seashore, with one clutch per box. Boxes containing the eggs and sand were flown by single-engine aircraft to the National Seashore were they were tended by NPS personnel during incubation. Upon emergence, the hatchlings were imprinted by brief exposure to the Padre Island beach and surf.

Clutches of hatchlings were placed in wax-coated, corrugated cardboard boxes for shipment to Galveston. Some of the boxes containing hatchlings were transported by NPS station wagon from the National Seashore to the U.S. Navy Base at Corpus Christi, and thence to Galveston's Schole's Airfield aboard a U.S. Navy aircraft. The boxes were then transferred by pick-up truck to the head start facilities. Other boxes were transported by NPS station wagon from

* *National Marine Fisheries Service*

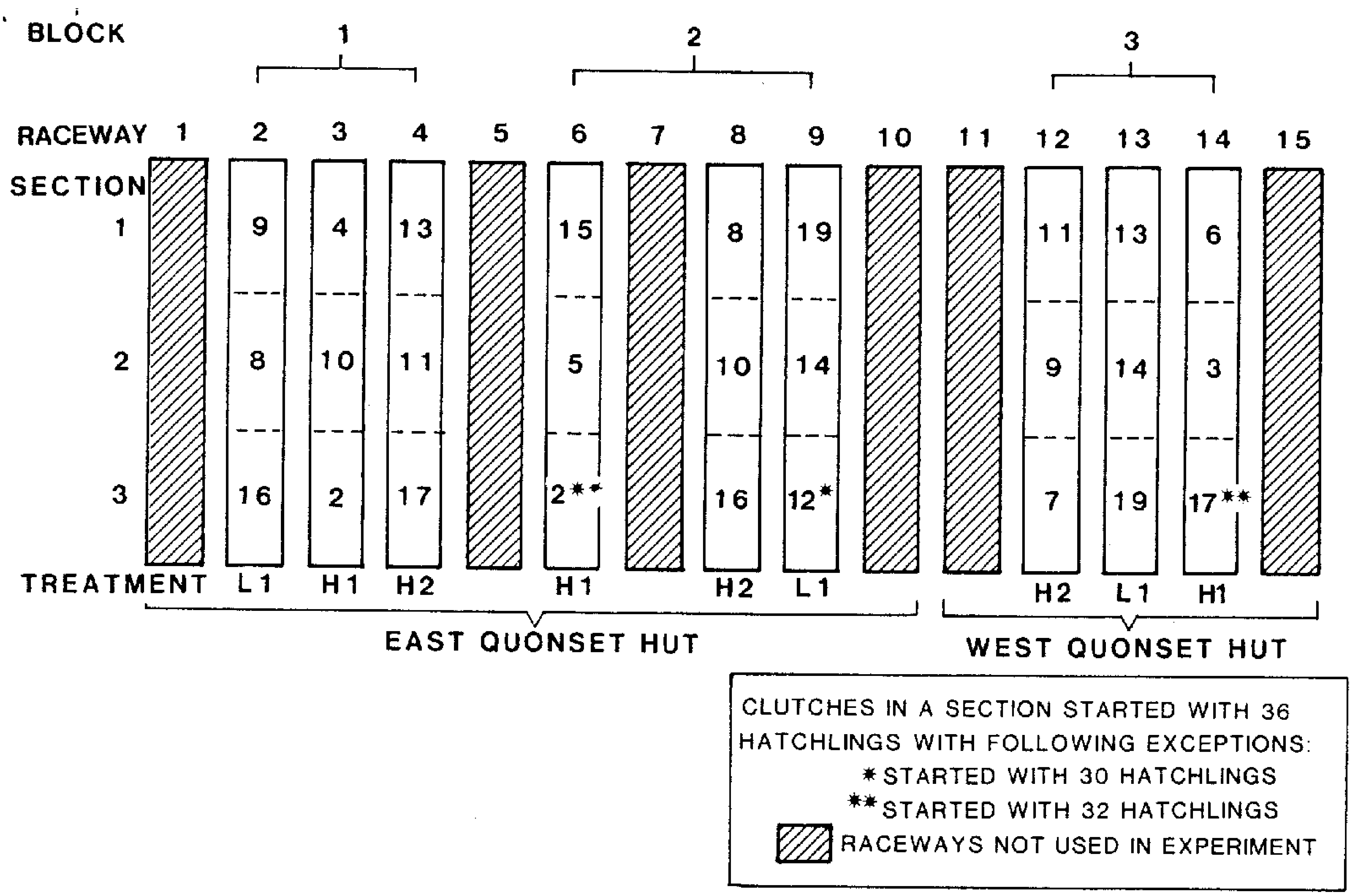

Figure 1. Physical layout of the randomized complete block design for the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class (three blocks of three raceways with three treatments [H1, H2 and L1] randomly assigned to each; clutch numbers are shown by section within raceways).

the National Seashore to the head start facilities. All boxes contained a 2.5 cm layer of moistened polyurethane foam to cushion the hatchlings and prevent their desiccation during transport.

Rearing Facilities

Hatchlings in the experiment were reared in buckets placed in nine rectangular (1.8 x 6.1 m), fiberglass raceways (Figure 1) located in two polyethylene sheeting-covered quonset huts (Fontaine *et al.*, 1985, 1989). Each raceway contained approximately 3,140 liters of seawater. Suspended within each raceway were 108 yellow, plastic buckets (9.5-liter capacity). Turtles were reared in isolation from each other in these buckets, one turtle per bucket, to prevent their attacking, biting and injuring one another, as they are very aggressive (Klima and McVey, 1982; Clary and Leong, 1984). The bottoms of the buckets were perforated with 1.3-cm diameter holes, to allow exchange of seawater and liberation of turtle excrement and uneaten food. Forced-air, gas-fired heaters maintained warm air and water temperatures within the quonset huts during the winter.

Turtles in a raceway were all treated similarly with regard to feeding, cleaning of the raceway and management of seawater and wastewater. Raceways were drained, flushed by hosing with fresh (tap) water, and refilled with clean seawater three times a week. Once each week, all raceways were drained, scrubbed with brushes and flushed to remove attached algae, uneaten food and accumulated waste materials. Temperature, salinity and pH were monitored in the nine raceways used in the experiment.

Seawater for the raceways was pumped from the Gulf of Mexico through well-points buried in the sand below water at the Galveston beachfront (Fontaine *et al.*, 1985, 1989). After a period allowed for settling of particulates, the seawater was stored in fiberglass reservoirs near the quonset huts, and was used as needed. The reservoirs were shrouded with insulation and were outfitted with emersion heaters to keep the seawater warm during winter.

Feeding Experiment

Experimental Design

The experiment was conducted in parallel with that of Landry (1989). A randomized complete block design was used for the experiment to isolate possible microenvironmental variation among raceways from the treatment effects

(Table 1, Figure 1). For this purpose, the nine raceways used in the experiment were divided into three adjacent groups of three raceways each, and these groups were treated as blocks numbered 1 - 3. One of the three treatments (Table 1) was randomly assigned to each raceway within each block.

Prior to receiving the hatchlings, we anticipated that we could reduce possible effects of variation in age and other characteristics of clutches on the treatment effects by distributing the hatchlings in such a way that each raceway contained three different clutches, with the constraint that clutches assigned to a given raceway were as close in age as possible. Location of clutches within each raceway was randomized among three sections of 36 buckets each (Figure 1). Variation among clutches within raceways was treated as a random nested effect within raceways. All clutches except clutches 1 and 18 contributed hatchlings to the experiment.

Clutches hatched between July 15-23, 1984, so they varied in age only slightly more than a week. Therefore, all clutches were considered the same age, and their age in days was calculated from the mean hatch date of July 18. To calculate the mean hatch date, each date was weighted according to the number of hatchlings that emerged on that date. The modal and median hatch dates also were 18 July.

Seven clutches (3-7, 12 and 15) used in the experiment did not contain enough hatchlings to be assigned randomly to more than one block, but the remaining 10 clutches (2, 8-11, 13, 14, 16, 17 and 19) were large enough to be divided between two raceways, with each of the two raceways being in different blocks (Figure 1). However, section 3 of raceways 6, 9 and 14 contained fewer than the full complement of 36 hatchlings, because clutches 2, 12 and 17 were not large enough to provide full complements of 36 each to these raceways.

Foods and Feeding

Two commercial diets were used in head starting the 1984 year-class (see Fontaine *et al.*, 1985; Caillouet *et al.*, 1986a). Both were dry, floating, pelleted diets. The experiment began on August 22, 1984, with a diet manufactured by Central Soya and Subsidiaries, Decatur, Ind. This diet had to be replaced after November 10 because the new batch we received did not have the same floating characteristics of the earlier batches. We switched to a sea turtle chow (a modified trout chow) manufactured by Purina, Richland, Ind. The latter was the same diet used by the Cayman Turtle Farm (1983), Ltd., Grand Cayman, B.W.I., for rearing green turtles (*Chelonia mydas*), and it had been recommended earlier by the farm's director, James Wood (personal communication, August 1984).

The standard feeding technique developed by Fontaine *et al.* (1985) in head starting Kemp's ridleys of the 1981-1983 year-classes was to set the food ration per turtle as a percentage of the arithmetic mean weight per turtle, determined by weighing samples of turtles at roughly monthly intervals during head starting. The procedure was modified for the experiment by substituting geometric mean weight for arithmetic mean weight in the calculations of food ration. This was done because the variance in weight among head started Kemp's ridleys increases with average weight in such a way that a logrithmic transformation of weights eliminates such heterogeneity of variance (Caillouet *et al.*, 1986b). Once the weight of food per turtle was calculated for a given raceway, the food was distributed to each turtle by volumetric measure based on the weight: volume ratio for the food.

Through September 4, 1984, all hatchlings received the same daily ration based on approximately 10 percent of their initial arithmetic mean weight (see Caillouet *et al.*, 1986a, Table 15). Feeding under the experimental protocol (Table 1) began on September 5, but August 22 was considered the start of the experiment because it was the date on which the turtles were first weighed for the experiment (Table 2). Weighings continued at 22-29 day intervals (Table 2) until February 28, 1985, when the experiment was terminated as a consequence of some turtles having outgrown their buckets.

Two experimental feeding levels were tested in the feeding experiment (Tables 1 and 3). Feeding level was represented in two ways: (1) feeding rate expressed as a percentage of geometric mean body weight per turtle and (2) food ration expressed as the weight of food fed per turtle per day. At the beginning of the experiment, the high feeding level represented approximately 1.3 times as much food by weight as the low level, and it reached approximately 2.5 times the low level by the end of the experiment. This shift merely reflected the differences in growth among turtles in the different treatments. Because day to day conditions in the raceways were affected by temperature, the amount of uneaten food, and the amount of turtle excrement, the experimental daily food rations had to be altered from time to time. For example, when bloating caused by overfeeding occurred, feeding was interrupted for a day or two to allow the turtles to recover. After the experiment, the actual rations as well as the feeding rates in percentage of body weight were recalculated for each interval between weightings (Table 3). While the feeding rate was reduced gradually over the period of the experiment, the food ration increased because the turtles were growing.

Because feeding rates were controlled as a percentage of mean body weight during the experiment (Table 3), for any given feeding rate the actual food ration received by each turtle in a given raceway varied depending upon the weight per turtle in that raceway at the beginning of each interval when feeding rate was adjusted (see Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). For this reason, analyses of variance were conducted on daily food ration (Table 4) and

Table 1. Treatments in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Daily feeding frequency	Daily feeding levels[a] High	Low
Once: in the morning	Treatment H1	Treatment L1
Twice: once in the morning and once in the afternoon	Treatment H2 (Control)[b]	(not tested)

[a]See Table 3 for food rations and feeding rates.
[b]This was comparable to the old system of feeding as regards feeding level and frequency (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b).

Table 2. Sequence and dates of weighings and time intervals between weighings in the feeding experiment on Kemp's ridly sea turtles of the 1984 year-class.

Weighing sequence	Date	Time interval	Duration of time interval, Days[a]
1	August 22, 1984		
		1	22
2	September 13		
		2	28
3	October 11		
		3	28
4	November 8		
		4	28
5	December 6		
		5	27
6	January 2, 1985		
		6	29
7	January 31		
		7	28
8	February 28		

[a]Represents the number of days lapsed from and including one date of weighing to the day prior to the next consecutive date of weighing.

Table 3. Daily food ration (grams)[a] and daily feeding rate (%)[b] averaged by treatment and time interval during the feeding experiment on the 1984 year-class of Kemp's ridley sea turtles.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1 grams (%)	High level twice/day H2 grams (%)	Low level once/day L1 grams (%)	Diet
	1	Aug. 22-Sept. 12, 1984	2.0 (6.3)	2.1 (6.0)	1.6 (4.7)	Central Soya
1	2	Sept. 13 - Oct. 10	1.9 (3.3)	2.2 (3.3)	1.2 (1.9)	"
	3	Oct. 11 - Nov. 7	4.3 (4.6)	5.0 (4.4)	2.6 (2.9)	"
NA[c]	4	Nov. 8 - Dec. 5	3.9 (2.5)	4.8 (2.6)	2.1 (1.6)	Central Soya – Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	2.3 (1.4)	2.5 (1.3)	1.2 (0.8)	Purina
2	6	Jan. 2 - Jan. 30	2.9 (1.5)	3.1 (1.3)	1.4 (0.9)	"
	7	Jan. 31 - Feb. 27	3.0 (1.2)	3.5 (1.2)	1.3 (0.7)	"

[a]Daily food ration was determined for each raceway (because all turtles in a given raceway received the same ration) by dividing the total grams of dry food per turtle per day during a given time interval between weighings by the number of days in the interval.

[b]Daily feeding rate was determine for each clutch within a given raceway by expressing daily food ration for a given time interval between weighings as a percentage (%) of the geometric mean body weight (wet) at the beginning of each time interval.

[c]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 4. Analysis of variance of daily food ration[a] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	0.36412	5.31 *[b]
Treatments, T	2	16.26393	237.26 *
H1 & H2 vs. L1	(1)	(30.94249)	451.39 *
H1 vs. H2	(1)	(1.58537)	23.13 *
Time interval, I	6	6.46791	94.35 *
T x I interaction	12	0.51202	7.47 *
Experimental error	40	0.06855	

[a]Daily food ration was determined for each raceway (because all turtles in a given raceway received the same ration) by dividing the total grams of dry food per turtle per day during a given time interval between weighings by the number of days in the interval.

[b]* = significant at $P \leq 0.05$.

Table 5. Analysis of variance of transformed[a] daily feeding rate[b] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	0.05513	0.20 ns[c]
Treatments, T	2	74.79456	271.81 *[d]
H1 & H2 vs. L1	(1)	(148.48420)	539.61 *
H1 vs. H2	(1)	(1.10494)	4.02 ns
Time interval, I	6	249.54165	906.86 *
T x I interaction	12	0.89448	3.25 *
Experimental error	40	0.27517	
Clutches within raceways	126	0.53264	

[a]Angular (arcsine) transformation (see Sokal and Rohlf, 1981, p. 427-428).

[b]Daily feeding rate was determined for each clutch within a given raceway by expressing daily food ration for a given time interval between weighings as a percentage (%) of the geometric mean body weight (wet) at the beginning of each time interval.

[c]ns = non-significant at $P = 0.05$.

[d]* = significant at $P \leq 0.05$.

Table 6. Analysis of variance of transformed[a] proportion of survivors[b] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	219.00704	2.42 ns[c]
Treatments, T	2	79.30744	0.88 ns
H1 & H2 vs. L1	(1)	(0.01040)	0.00 ns
H1 vs. H2	(1)	(158.60448)	1.75 ns
Experimental error	4	90.44190	
Clutches within raceways	18	137.91116	

[a]Angular (arcsine) transformation (see Sokal and Rohlf, 1981, p. 427-428).

[b]Determined for each clutch within a raceway by dividing the number or survivors at the end of the experiment by the number of hatchlings at the beginning of the experiment.

[c]ns = non-significant at $P = 0.05$

on transformed daily feeding rate (Table 5). An angular transformation (Sokal and Rohlf, 1981, p. 427-428) was used for daily feeding rate because percentages usually require such transformation to meet assumptions of analysis of variance.

Two feeding frequencies were tested at the high feeding level (Tables 1 and 3, Figure 1): once-daily in the morning (Treatment H1), and twice-daily, once in the morning and once in the afternoon (Treatment H2). For twice-daily feeding, the daily ration was divided into two equal portions, so the turtles in Treatments H1 and H2 received the same amount of food per day. The low level of feeding was only once-daily in the morning (Treatment L1). Treatment H2 was considered a control as it represented the old system of feeding (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). The combination of low feeding level and twice-daily feeding was not tested.

Sampling for Weighings

To determine growth and adjust feeding rates, wet body weights were determined from random samples of 10 turtles per clutch in each raceway at each weighing during the experiment (Table 2). Weighings were made to the nearest 0.1 gram on an O'Haus, triple-beam balance. The balance pan was dried and the balance re-zeroed after consecutive weighings of three turtles. The geometric mean weight of the combined samples within a raceway was used as the basis for adjusting feeding rate.

Survival

Survival from the beginning to end of the experiment was calculated for each clutch in each raceway and was expressed in percentage.

Results

Feeding Rations and Rates

In the analysis of variance for daily food ration (Table 4), all main effects and the treatment x time interval interaction were significant (refers throughout this paper to the critical region of rejection of null hypotheses at $P \leq 0.05$). Orthogonal contrasts among treatments (Table 4) showed that the daily food ration was significantly and substantially higher at the high feeding level (as expected), but also that the ration for twice daily feeding was significantly and slightly higher when split into twice-daily feedings than when given in only one feeding (Table 3), probably an artifact of the pellet size in relation to the use of two different sizes of volumetric measures to dole out the pellets for the two feeding levels. The significant differences in food ration among time intervals and the significant interaction between treatments and time intervals (Table 4) simply reflected the effects of differential growth of the turtles from different clutches and raceways within treatment-time interval combinations, which in turn influenced the adjustment of feeding rates.

As expected, daily feeding rate differed significantly between the high and low levels of feeding but not between the two frequencies of feeding at the high level (Table 5). As with daily food ration, there were significant differences in feeding rate among time intervals and a significant interaction between treatment and time interval. Again, this reflected differential growth of the turtles which in turn influenced the subsequent amounts of food they received. Daily feeding rate was reduced over time, because the turtles require a decreased feeding rate as they grow larger (Fontaine *et al.*, 1985). The analysis of variance for daily feeding rate included the random nested effect of clutches within raceways, because feeding rate was recalculated on a clutch-within-raceway basis retrospectively to assess variability generated by differences in growth from clutch to clutch.

Survival

Analysis of variance of transformed proportion of survivors detected no significant differences in main effects or interaction (Table 6), so the treatments had no significant effect on survival. Overall survival was 95.8 percent for the experiment.

Gross Food Conversion Efficiency

Gross food conversion efficiency, C, was calculated for each clutch in each raceway over the intervals between weighings as follows:

$$C = F/G$$

where

F = food ration in grams of dry food fed per turtle per day, and
G = weight gain (wet) per turtle per day.

G was calculated by dividing the change in geometric mean weight per turtle between two consecutive weighings by the number of days in the interval between weighings. Usually this resulted in a weight gain, but in some cases there was a weight loss so the weight change was negative. The food ration, F, was calculated by dividing the sum of the daily quantities of food fed per turtle during an interval between weighings by the number of days in the interval. Gross food conversion efficiency does not represent actual food intake and assimilation, because some of the food was not eaten. It is only an index.

Gross food conversion efficiency is summarized in Table 7. Time interval 4 produced aberrant conversion efficiencies because of the problems that began to develop in time interval 3 with the Central Soya diet. In interval 4, growth slowed and at the low level of feeding some of the clutches lost weight producing negative efficiencies. Food was in excess because the turtles were not utilizing it and were either growing slowly or losing weight. Therefore, conversion efficiencies in interval 4 were disregarded (Table 7), and separate analyses of variance were conduced for two phases of the experiment, the first involving only the Central Soya diet and the second involving only the Purina diet (Table 8).

In phase 1, the gross food conversion efficiency was significantly higher at the high level of feeding than at the low level of feeding, and it varied significantly among time intervals (Table 8). No other main effects nor the interaction were significant. During phase 2, none of the main effects nor the interaction were significant, so the differences observed in phase 1 apparently had no significant residual or carry-over influence on those of phase 2.

Weight Gain

Weight gain, G, is summarized in Table 9. Analysis of variance detected significantly greater weight gain at the high level of feeding than at the low, but in addition the twice-daily feeding produced significantly greater weight gain than the once-daily feeding at the high feeding level (Table 10). There also were significant differences in weight gain among time intervals. Interval 4 had the smallest average weight gain.

Growth Rate Index

The growth rate index, b, was calculated by linear regression analysis for each clutch in each raceway. This was done separately for the two phases of the experiment, so each line was based on 40 paired observations (10 per weighing for four consecutive weighings per phase). Each line was fitted to logarithmically transformed weights regressed on the square roots of age as follows:

$$\ln(W) = \ln(a) + bT^{1/2}$$

where,

W = wet weight in grams,
T = age in days from the mean hatch date,
b = slope (an index of growth rate), and
a = empirical constant.

This growth model is similar to that derived by Caillouet *et al.* (1986b) to describe first-year growth in weight per turtle for year-classes 1978-1983 of head started Kemp's ridleys. The exponential equivalent of the model is:

$$W = ae^{bT^{1/2}}$$

where,

e = base of natural logarithms.

Growth rate index is summarized in Table 11, and analyses of variance detected significantly greater growth rates at the high level of feeding than at the low in both phases of the experiment (Table 12). Again, the transitional and aberrant time interval 4 was disregarded in the analyses. There were no significant differences in growth rate between once and twice daily feedings at the high level in either of the two phases of the experiment.

Environmental Variables

Average seawater temperature, salinity and pH were calculated for each of the nine raceways for each of the seven time intervals. Analyses of variance detected significant differences among time intervals for all three environmental variables (Table 13). Variations in temperature, salinity and pH probably reflected seasonal changes. Treatments had no significant effect and there were no significant interactions between treatments and time intervals for these variables. Time interval 4 had the lowest temperature and salinity in the time series which may have contributed to the aberrant gross food conversion efficiencies and low or negative weight gains in interval 4.

Discussion

There have been numerous studies of growth of sea turtles of various species on artificial diets in captivity (Hildebrand and Hastel, 1927; Caldwell, 1962; Uchida, 1967; Stickney, White and Perlmutter, 1973; Kaufmann, 1975; LeBrun, 1975; Witham and Futch, 1977; Whitaker, 1979; Witzell, 1980; Wood and Wood, 1981; Nuitja and Uchida, 1982;

Table 7. Gross food conversion efficiency, C[a], averaged by treatment and time interval during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1	Treatment: High level twice/day H2	Treatment: Low level once/day L1	Diet
			C[a]	C	C	
	1	Aug. 22 - Sept. 12, 1984	1.8	1.3	1.3	Central Soya
1	2	Sept. 13 - Oct. 10	1.6	1.5	1.2	"
	3	Oct. 11 - Nov. 7	1.9	2.1	1.7	"
NA[b]	4	Nov. 8 - Dec. 5	16.0	183.7	-0.3	Central Soya-Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	2.3	0.8	3.6	Purina
2	6	Jan. 2 - Jan. 30	1.8	1.8	2.2	"
	7	Jan. 31 - Feb. 27	2.6	2.0	2.1	"

[a]C was determined for each clutch within a given raceway by dividing F, the food ration in grams of dry food per turtle per day during a given time interval between weighings by G, the weight gain (wet) per turtle per day during the interval. Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval. Note that averages in this table are not the same as those one might obtain by dividing average daily food rations in Table 3 by corresponding average daily weight gains in Table 9, because C was determined for every clutch in each raceway and for each time interval before being averaged herein.
[b]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 8. Analysis of variance of gross food conversion efficiency [a] for the two phases of the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase 1

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.27881	0.88	ns[b]
Treatments, T	2	1.05733	3.33	ns
H1 & H2 vs. L1	(1)	(1.72356)	5.43	*[c]
H1 vs. H2	(1)	(0.39111)	1.23	ns
Time interval, I	2	1.94480	6.13	*
T x I interaction	4	0.22622	0.71	ns
Experimental error	16	0.31723		
Clutches within raceways	54	0.27108		

Phase 2

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.34443	0.04	ns
Treatments, T	2	8.58744	1.11	ns
H1 & H2 vs. L1	(1)	(10.27210)	1.33	ns
H1 vs. H2	(1)	(6.90277)	0.89	ns
Time interval, I	2	0.67243	0.09	ns
T x I interaction	4	5.55306	0.72	ns
Experimental error	16	7.73725		
Clutches within raceways	54	4.79946		

[a]C was determined for each clutch within a given raceway by dividing F, the food ration in grams of dry food per turtle per day during a given time interval between weighings by G, the weight gain (wet) per turtle per day during the interval. Daily weight gain was determined for each clutch withing a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]ns = non-significant at $P = 0.05$.
[c]* = significant at $P \leq 0.05$.

Table 9. Daily weight gain[a] averaged by treatment and time interval during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment High level once/day H1	Treatment High level twice/day H2	Treatment Low level once/day L1	Diet
			grams	grams	grams	
	1	Aug. 22 - Sept. 12, 1984	1.2	1.6	1.3	Central Soya
1	2	Sept. 13 - Oct. 10	1.2	1.6	1.0	"
	3	Oct. 11 - Nov. 7	2.3	2.8	1.6	"
NA[b]	4	Nov. 8 - Dec. 5	0.4	0.5	0.4	Central Soya-Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	1.2	1.8	0.6	Purina
2	6	Jan. 2 - Jan. 30	1.9	2.1	0.9	"
	7	Jan. 31 - Feb. 27	2.1	2.5	0.6	"

[a]Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 10. Analysis of variance of daily weight gain[a] during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	1.04346	1.64	ns[b]
Treatments, T	2	12.96030	20.41	*[c]
H1 & H2 vs. L1	(1)	(22.56014)	35.52	*
H1 vs. H2	(1)	(3.36046)	5.29	*
Time interval, I	6	8.39384	13.22	*
T x I interaction	12	1.11699	1.76	ns
Experimental error	40	0.63505		
Clutches within raceways	126	0.37152		

[a]Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]ns = non-significant at $P = 0.05$.
[c]* = significant at $P \leq 0.05$.

Table 11. Growth rate index, b[a], averaged by phase and treatment during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment High level once/day H1	Treatment High level twice/day H2	Treatment Low level once/day L1	Diet
			b[a]	b	b	
1	1-3	Aug. 22 - Nov. 7, 1984	0.327	0.354	0.286	Central Soya
2	5-7	Dec. 6, 1984 - Feb. 27, 1985	0.201	0.196	0.115	Purina

[a]The slope of the regression of the natural logarithm of weight (grams) on the square root of age (days). Growth rate index was determined for each clutch within a given raceway.

Table 12. Analysis of variance of growth rate index, b[a], during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom		Mean square	F	
Phase 1					
Blocks	2		0.000429	0.48	ns[b]
Treatments, T	2		0.010610	11.84	*[c]
H1 & H2 vs. L1		(1)	(0.017858)	19.93	*
H1 vs. H2		(1)	(0.003362)	3.75	ns
Experimental error	4		0.000896		
Clutches within raceways	18		0.000752		
Phase 2					
Blocks	2		0.003689	3.24	ns
Treatments, T	2		0.021075	18.54	*
H1 & H2 vs. L1		(1)	(0.042056)	36.99	*
H1 vs. H2		(1)	(0.000093)	0.08	ns
Experimental error	4		0.001137		
Clutches within raceways	18		0.000904		

[a]The slope of the regression of the natural logarithm of weight (grams) on the square root of age (days). Growth rate index was determined for each clutch within a given raceway.
[b]ns = non-significant at $P = 0.05$.
[c]* = significant at $P \leq 0.05$.

Hadjichristophorou and Grove, 1983; Frazer and Schwartz, 1984; Rajagopalan, 1984; LeGall, 1985; and Lebeau, 1986), but few such studies have been conducted on Kemp's ridley (Caldwell, 1962; Pritchard and Márquez, 1973; Klima and McVey, 1982; Caillouet and Koi, 1985; Caillouet *et al.*, 1986b and Landry, 1989). Our study on Kemp's ridley was a logical sequel to that of Caillouet *et al.* (1986b) because it stressed statistical design and analysis not possible under the uncontrolled conditions of the previous head starting efforts involving this species.

Our results showed clearly that the Kemp's ridleys receiving more food exhibited the highest weight gains and growth rate indices, as might be expected. However, for the high level of feeding, the turtles receiving the entire daily ration in one feeding per day had a smaller daily weight gain than those in which the daily ration was divided into two separate feedings. Again, this was not surprising because the turtles fed twice-daily grew faster and therefore received more food based on a percentage of their body weight under the feeding technique developed by Fontaine *et al.* (1985). Also, this may have been due in part to an artifact of using different size volumetric measures to dole out feed pellets to the turtles, with resulting difficulty in measuring out small quantities of pellets by volume. While this is a practical technique which saves time in feeding large numbers of turtles, it is obviously inadequate for definitive studies of food intake and growth. There was no apparent difference in the response to once-daily vs. twice-daily feeding (at the high level) as measured by the growth rate index developed by Caillouet *et al.* (1986b). This was probably due to the fact that there were fewer degrees of freedom for the experimental error mean square in analyses of variance of the growth rate index as compared to degrees of freedom for experimental error in the analyses of variance of weight gain.

Gross food conversion efficiency was best (lowest amount of food fed per unit increase in weight per turtle) at the low level of feeding, but only during the first phase of the experiment during which the Central Soya diet was being used. During the second phase in which the Purina diet was used, the effects of the two different feeding levels on gross food conversion efficiency were indistinguishable.

The shift in diet during the experiment was an unplanned event, a consequence of unanticipated problems with the Central Soya diet that had not occurred in prior years of its use. Because the shift in diet occurred sequentially, the experiment did not provide a comparison of the two diets. The main consideration was the health and safety of the endangered Kemp's ridley turtles, so the experimental protocol had to be subservient.

A slowing of growth in captive-reared Kemp's ridleys during winter, associated with cooling of the water, has been observed (Caillouet and Koi, 1985; Caillouet *et al.*, 1986b). Lowered temperature may account in part for the slowing of growth and the poorer food conversion efficiencies observed in the experiment during time interval 4 (November 8 - December 5, 1984) which had the lowest average temperature and salinity of any of the time intervals. Nonetheless,

Table 13. Means[a] (A) and analyses of variance for temperature (B), salinity (C) and pH (D) during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

A. Means

Time interval	Mean temperature, °C	Mean salinity, ppt	Mean pH
1	25.7	29.1	-[b]
2	22.7	29.3	7.2
3	24.1	24.6	7.3
4	21.1	23.6	7.4
5	22.9	27.2	-
6	21.9	26.2	-
7	23.1	28.8	7.5

B. Temperature, °C

Source of variation	Degrees of freedom		Mean square	F	
Blocks	2		0.01300	0.23	ns[c]
Treatments, T	2		0.07889	1.40	ns
H1 & H2 vs. L1		(1)	(0.08770)	1.56	ns
H1 vs. H2		(1)	(0.07008)	1.24	ns
Time interval, I	6		19.56146	347.51	*[d]
T x I interaction	12		0.00354	0.06	ns
Experimental error	40		0.05629		

C. Salinity, ppt

Source of variation	Degrees of freedom		Mean square	F	
Blocks	2		0.12749	2.14	ns
Treatments, T	2		0.01892	0.32	ns
H1 & H2 vs. L1		(1)	(0.02388)	0.40	ns
H1 vs. H2		(1)	(0.01397)	0.23	ns
Time interval, I	6		46.91016	786.03	*
T x I interaction	12		0.00395	0.07	ns
Experimental error	40		0.05968		

D. pH

Source of variation	Degrees of freedom		Mean square	F	
Blocks	2		0.00330	4.23	*
Treatments, T	2		0.00046	0.59	ns
H1 & H2 vs. L1		(1)	(0.00086)	1.10	ns
H1 vs. H2		(1)	(0.00007)	0.09	ns
Time interval, I	3		0.16910	216.79	*
T x I interaction	6		0.00022	0.28	ns
Experimental error	22		0.00078		

[a]Based on observations taken from each raceway, but not necessarily on every day within the time intervals. Averaged over raceways and days of observation within time intervals.
[b]– = insufficient number of observations.
[c]ns = non-significant at P = 0.05.
[d]* = significant at P $\leq$ 0.05.

temperature was better controlled in 1984 than in previous years.

The experimental feeding levels and frequencies had no apparent effect on survival, and overall survival during the experiment was very high (95.8 percent). Therefore, the turtles that received the least food showed no greater mortality than those that received the larger amounts based on our results.

Our results have considerable practical significance to the head starting of large numbers (1,000 to 2,000 per year) of Kemp's ridleys in captivity. Twice as much labor is required to feed the turtles twice per day than to feed them once per day. The turtles seem to be opportunistic feeders and will eat as many pellets as provided them until they are satiated. Additional food is wasted and causes problems in deterioration of seawater quality (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). Perhaps a single feeding per day would be adequate if the feeding rate were somewhat higher than the low feeding rate but lower than the high feeding rate used in our experiment.

Feeding rate expressed as a percentage of body weight provides a handy *rule of thumb* for feeding large numbers of Kemp's ridleys in mass production head starting. However, its use results in heavier feedings for faster-growing turtles. Some clutches exhibit better growth than others. With the typical mixture of several clutches in a single raceway, the practical question arises as to whether or not the feeding rate should be adjusted according to the average weight of a sample of turtles representing the raceway or samples from each clutch within the raceway. Our conventional practice has been to feed by raceway, basing the feeding rate on the average weight of turtles representing all clutches in the raceway. To do otherwise would be impractical. However, this restricts growth in faster growing clutches and may result in overfeeding of slower growing clutches. The problem can be lessened by putting clutches of equal age in a raceway, but this does not accommodate genetic differences that might affect growth performance of different clutches.

Acknowledgements

This work was conducted under Mexico's Instituto Nacional de la Pesca (INP) Permit 2534, U.S. Fish and Wildlife Service (FWS) Endangered and Threatened Species Permit PRT-676379 and Texas Parks and Wildlife Department (TPWD) Scientific Permit SP073. Kemp's ridley eggs were made available to the National Park Service (NPS) through the efforts of René Márquez Millan (INP, Mexico), Jack Woody and David Bowman (FWS, Albuquerque, N.M.), Pat Burchfield (Gladys Porter Zoo, Brownsville, Tex.) and their staffs. Robert King (NPS, Corpus Christi, Tex.) and his staff provided the "imprinted" hatchlings from these eggs. The U.S. Navy transported some of the hatchlings to Galveston.

The assistance of Marcel Duronslet, Dickie Revera, Christine Olguin, Julie Ramas, Denise Daley, David Smith, Ausbon Brown, Jr., Zoula Zein-Eldin, Medardo Olivarez, Fred Mattes and John Von Cannon was greatly appreciated.

HEART (Help Endangered Animals - Ridley Turtles), a special committee of the Piney Woods Wildlife Society of North Harris County College, chaired by Mrs. Carole Allen, Houston, Tex., provided the food for the 1984 year-class of Kemp's ridleys.

Literature Cited

Caillouet, C.W., Jr. 1984. Essai de prevention de l'extinction de la tortue de Kemp. Les Carnets de Zoologie (Bulletin of the Zoological Society of Quebec) 44(2):28-24.

Caillouet, C.W., Jr., C.T. Fontaine, T.D. Williams, S.A. Manzella, A.M. Landry, Jr., K.L. Indelicato, M.J. Duronslet and D.B. Rereva. 1988. Can we save Kemp's ridley sea turtle? Believe it or not!, p. 20-43. *In*: Peterson, K.H. (Editor), 10th International Herpetological Symposium on Captive Propagation and Husbandry, Zoological Consortium, Inc., Thurmont, MD, 206 p.

Caillouet, C.W., Jr., C.T. Fontaine, T.D. Williams, S.A. Manzella, D.B. Revera, D.B. Koi, K.L.W. Indelicato, M.G. Tyree, J.K., Leong, M.J. Duronslet and K.T. Marvin. 1986a. The Kemp's ridley sea turtle head start research project: an annual report for fiscal year 1985. NOAA Technical Memorandum NMFS-SEFC-174, ii plus 37 p., 29 Tables, 1 Figure and 5 Appendices.

Caillouet, C.W., Jr. and D.B. Koi. 1985. Patterns and variability in first-year growth in weight of captive-reared Kemp's ridley sea turtles: a graphical analysis. NOAA Technical Memorandum NMFS-SEFC-164, i plus 4 p. and 52 Figures.

Caillouet, C.W., Jr., D.B. Koi, C.T. Fontaine, T.D. Williams, W.J. Browning and R.M. Harris. 1986b. Growth and survival of Kemp's ridley sea turtle, *Lepidochelys kempi*, in captivity. NOAA Technical Memorandum NMFS-SEFC-186, iii plus 34 p., 12 Tables and 7 Figures.

Caldwell, D.K. 1962. Growth measurements of young captive Atlantic sea turtles in temperate waters. Los Angeles County Museum, Contributions in Science No. 50, 8 p.

Clary, J.C. III and J.K. Leong, 1984. Disease studies aid Kemp's ridley sea turtle headstart research. Herpetological Review 15 (3):69-70.

Fontaine, C.T., K.T. Marvin, T.D. Williams, W.J. Browning, R.M. Harris, K.L.W. Indelicato, G.A. Shattuck and R.A. Sadler. 1985. The husbandry of hatchling to yearling Kemp's ridley sea turtles (*Lepidochelys kempi*). NOAA Technical Memorandum NMFS-SEFC-158, iv plus 34p., 10 Tables, 22 Figures and 2 Appendices.

Fontaine, C.T., T.D. Williams, S.A. Manzella, M.G. Tyree and C.W. Caillouet, Jr. 1989. Kemp's ridley sea turtle head start operations of the NMFS SEFC Galveston Laboratory. (This volume.)

Frazer, N.B. and F.J. Schwartz. 1984. Growth curves for captive loggerhead turtles, *Caretta caretta*, in North Carolina, USA. Bulletin of Marine Science 34 (3):485-489.

Hadjichristophorou, M. and D.J. Grove. 1983. A study of appetite, digestion and growth in juvenile green turtle (*Chelonia mydas* L.) fed on artificial diets. Aquaculture 30:191-201.

Hildebrand, S.F. and C. Hastel. 1927. On the growth and behavior of loggerhead turtles in captivity. Proceedings of the National Academy of Sciences 13:374-377.

Kaufmann, R. 1975. Observaciones sobre el crecimiento de tortugas marinas en cautividad. Caldasia 11(53):139-150.

Klima, E.F. and J.P. McVey. 1982. Headstarting the Kemp's ridley turtle, *Lepidochelys kempi*, p. 481-487. *In*: Bjorndal, K.A. (Editor), Biology and Conservation of Sea Turtles, Proceedings of the World Conference on Sea Turtle Conservation, Smithsonian Institution Press, Washington, D.C., 583 p.

Landry, A.M, Jr. 1989. Morphometry of captive-reared Kemp's ridley sea turtles. (This volume.)

Lebeau, A. 1986. Un essai de grossissement en captivite de la tortue verte *Chelonia mydas* realise a Tahiti (Polynesie Francaise). Review Trav. de la Institute Peches Maritime 48(3 and 4):143-154.

LeBrun, G. 1975. Elevage a la Reunion de juveniles de la tortue verte *Chelonia mydas* (Linnaeus) 1758. Science et Peche, Bulletin de la Institute Peches Maritime No. 248. 25 p.

LeGall, J.-Y. 1985. Elevage de la tortue verte marine a l'ile de la Reunion (1978-1985). La Peche Maritime, July-August 1985, p. 434-440.

Mrosovsky, N. 1983. Conserving sea turtles. The British Herpetological Society, c/o the Zoological Society of London, 176 p.

Nuitja, I.N.S. and I. Uchida. 1982. Preliminary studies on the growth and food consumption of the juvenile loggerhead turtle (*Caretta caretta* L.) in captivity. Aquaculture 27:157-160.

Pritchard, P.C.H. and R. Márquez M. 1973. Kemp's ridley turtle or Atlantic ridley. International Union for the Conservation of Nature and Natural Resources Monograph No.2, 30 p.

Rajagopalan, M. 1984. Studies on the growth of olive ridley, *Lepidochelys olivacea*, in captivity. Central Marine Fisheries Research Institute Bulletin 35, p. 49-54.

Stickney, R.R., D.B. White and D. Perlmutter. 1973. Growth of green and loggerhead sea turtles in Georgia on natural and artificial diets. Bulletin of the Georgia Academy of Sciences 31:37-44.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Second Edition, W.H. Freeman and Company, New York, 859 p.

Uchida, I. 1967. On the growth of the loggerhead turtle, *Caretta caretta*, under rearing conditions. Bulletin of the Japanese Society of Scientific Fisheries 33(6):497-507.

Whitaker, R. 1979. Captive rearing of marine turtles. Journal of the Bombay Natural History Society 76(1):163-166.

Witham, R. and C.R. Futch. 1977. Early growth and oceanic survival of pen-reared sea turtles. Herpetologica 33(4):404-409.

Witzell, W.N. 1980. Growth of captive hawksbill turtles, *Eretmochelys imbricata*, in western Samoa. Bulletin of Marine Science 30(4):909-912.

Wood J.R. and F.E. Wood. 1981. Growth and digestibility for the green turtle (*Chelonia mydas*) fed diets containing varying protein levels. Aquaculture 25:269-274.